First order simulations of L-band RF gun for PERL

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Outline

- Introduction
- First order simulations of L-band RF gun for PERL
- Conclusion and Summary

Introduction

- **Requirements for beam parameters:**

  PERL requires 200 mA, and 0.5 mm-mrad normalized RMS Emittance. 25Mev at linac exit. For 1300Mhz RF gun it needs 150pc per bunch.

- **Why use L-band injector?**

  A. Same as main linac frequency, simplify operation, such as cost, synchronization.

  B. Potential for higher field operation ($\propto\sqrt{f}$) which can reduce space charge effect.

Major issues in L-Band RF Gun injector.

A. Field on cathode for a 1.6 cell RF gun:

Field gradient	45 C°	LN_2
50Mv/m	4.5MW	1.1MW
25Mv/m	1.1MW	350KW
15Mv/m	350KW	110KW

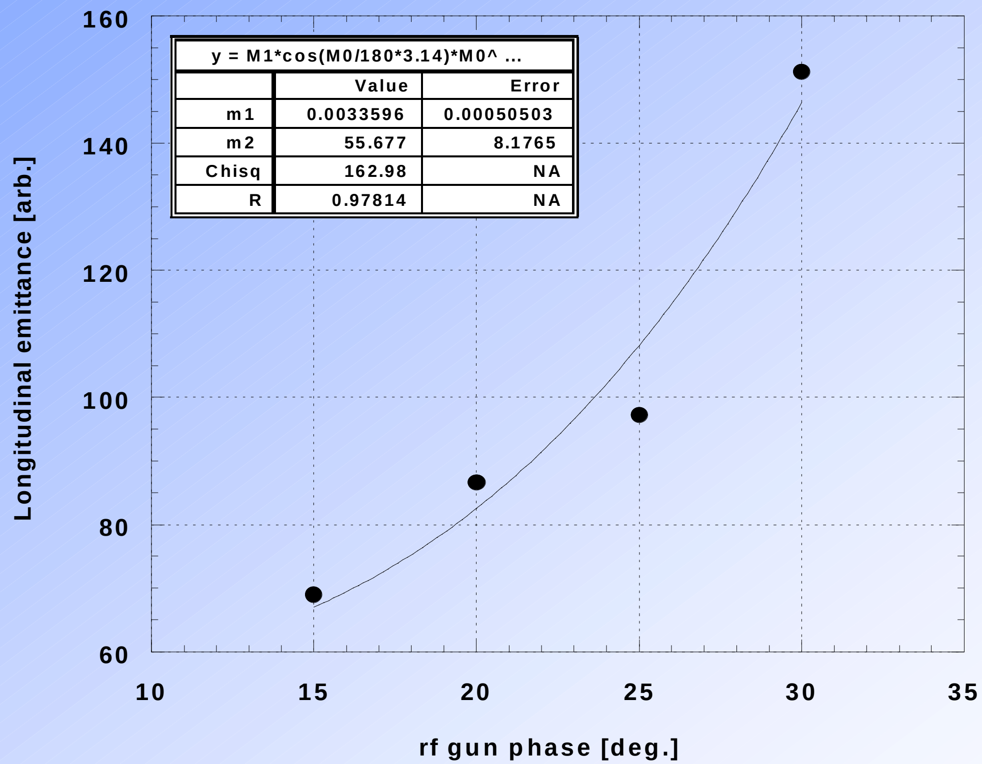
A LN_2 cooling method is proposed to improve Q and vacuum, therefore, reduce required power and extend cathode lifetime.

B. Heat dissipation problems:

We can relieve this problem by trying using a bigger size cavity works at higher order mode.

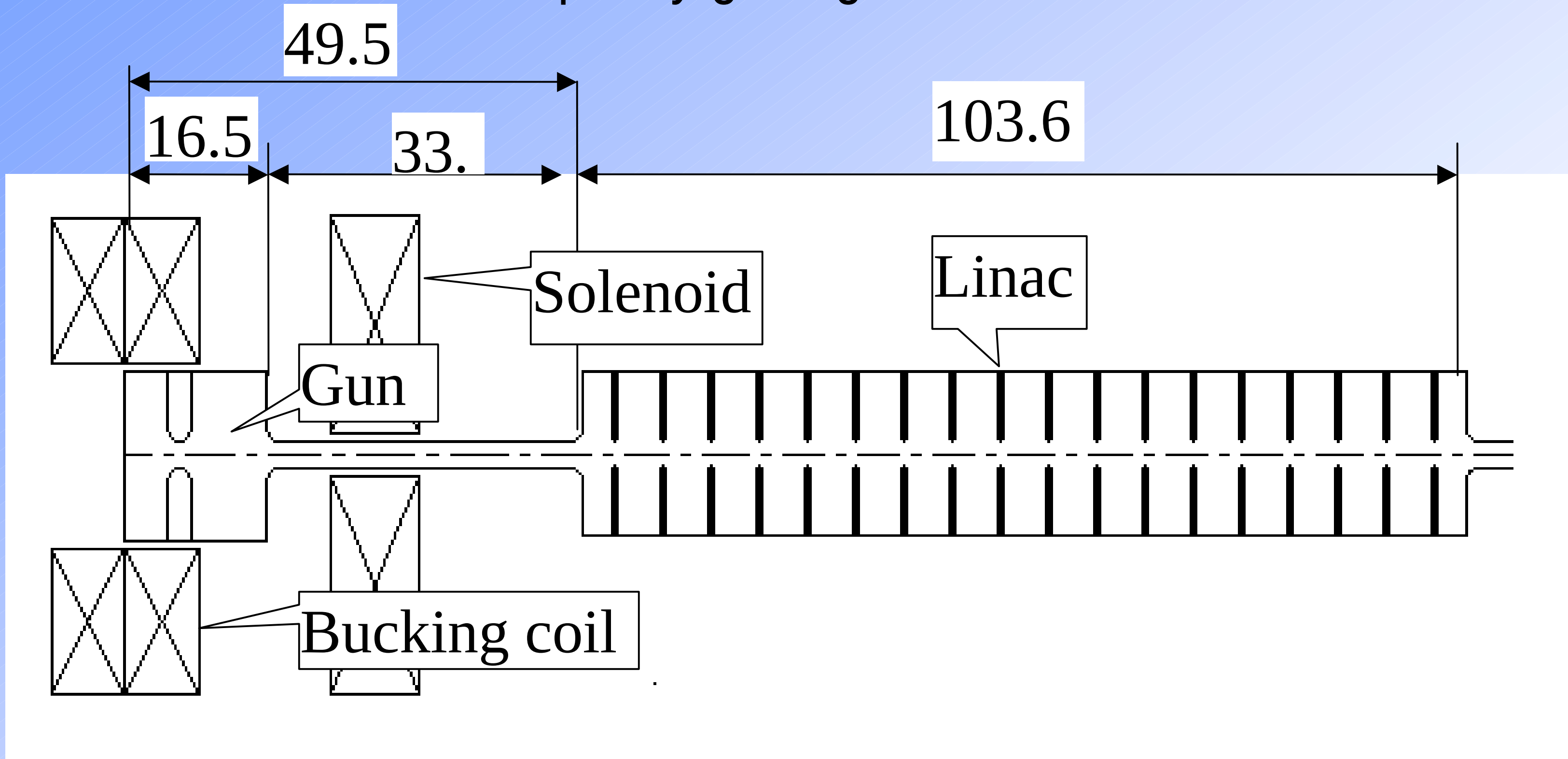
■ Longitudinal phase space ($\propto\varphi^3$):

Our major promise is to make the volume of 6-D phase space minimum at linac exit, Not only the transverse or longitudinal emittance. ($\varepsilon_z \times \varepsilon_x^2$)

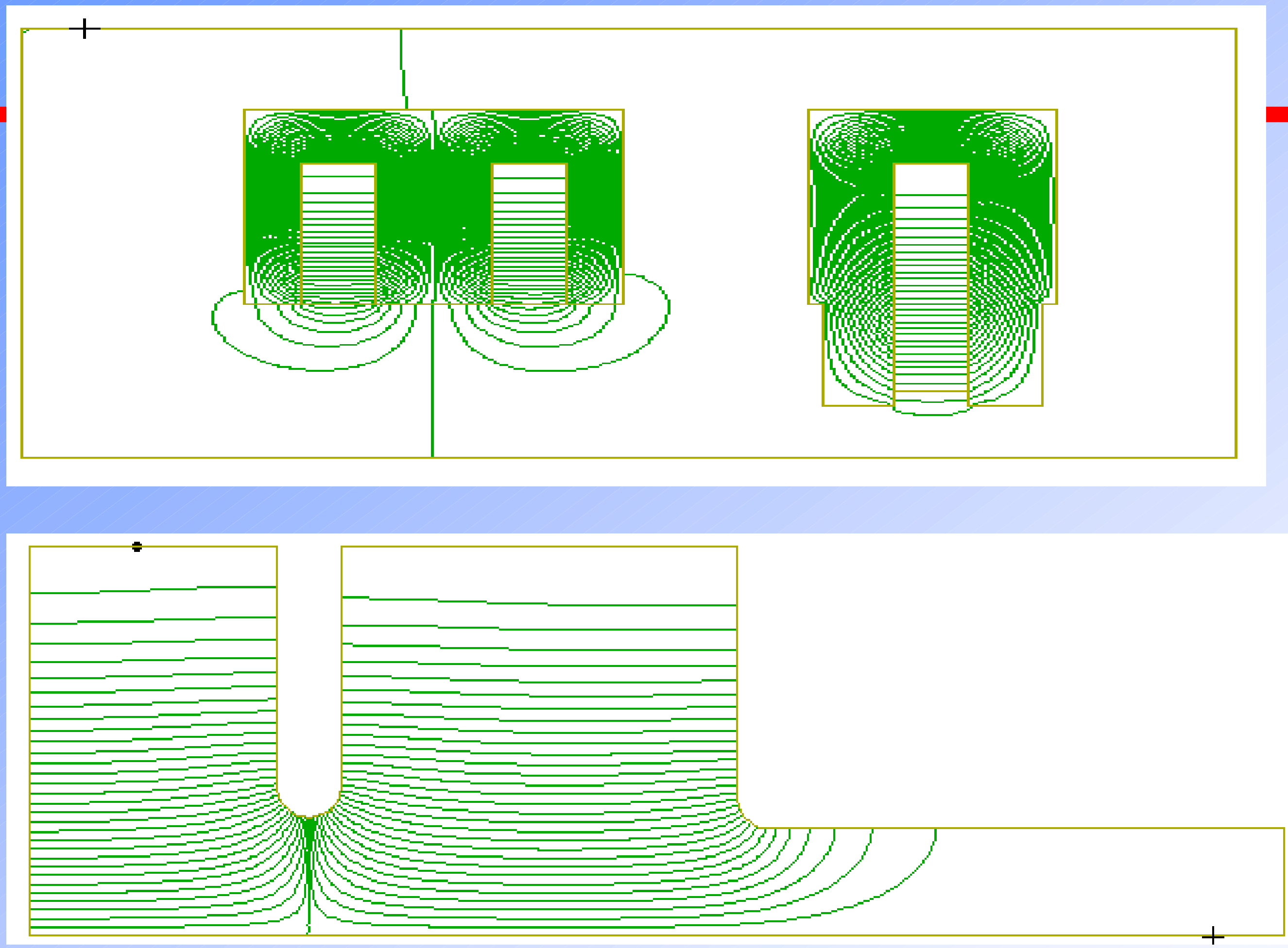


■ Introduction of ANL gun:

The starting point for our studies is based on ANL gun, which is originally used for high intensity short bunch injector. This saves our time of quickly getting start.



Schematic of L-band RF injector system at ANL(cm)



Field distributions of ANL solenoid and 1.5 cell gun

Simulation

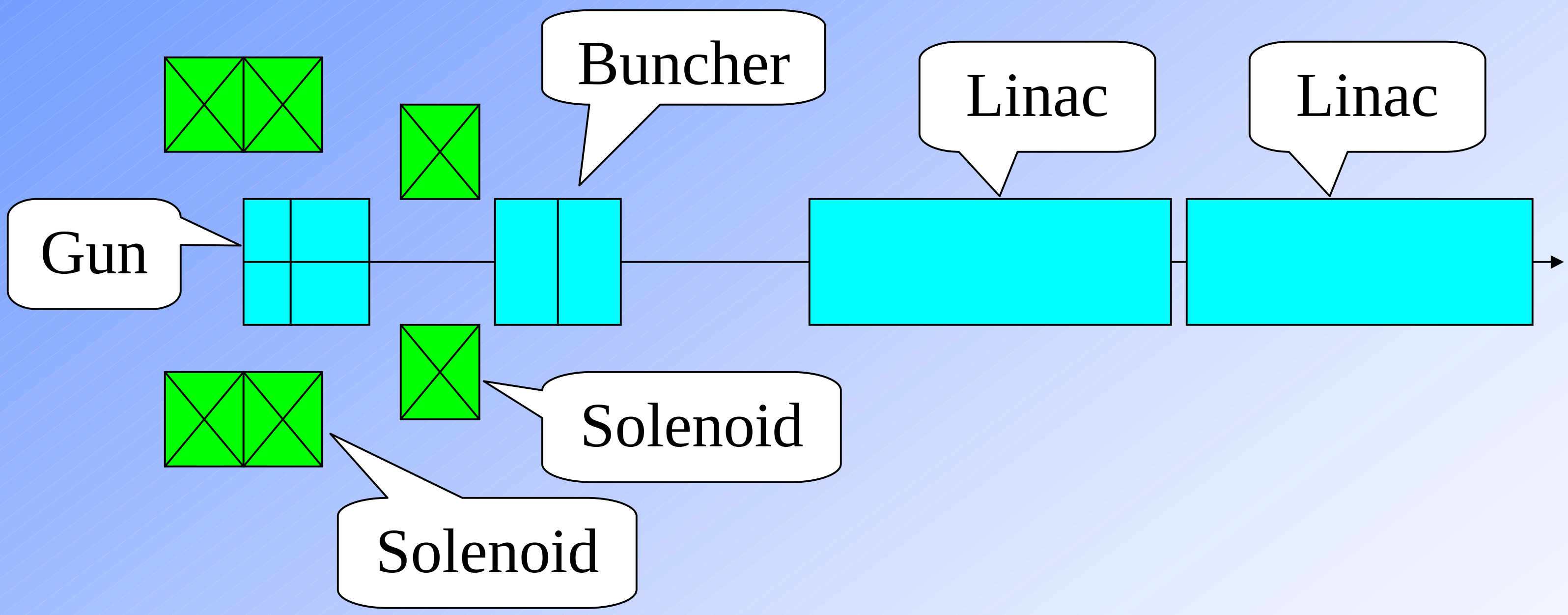
- Programs be used:

  POISSON (for solenoids).

  SUPERFISH (Gun, Buncher and accelerating structures)

  PARMELA (for beam dynamics).

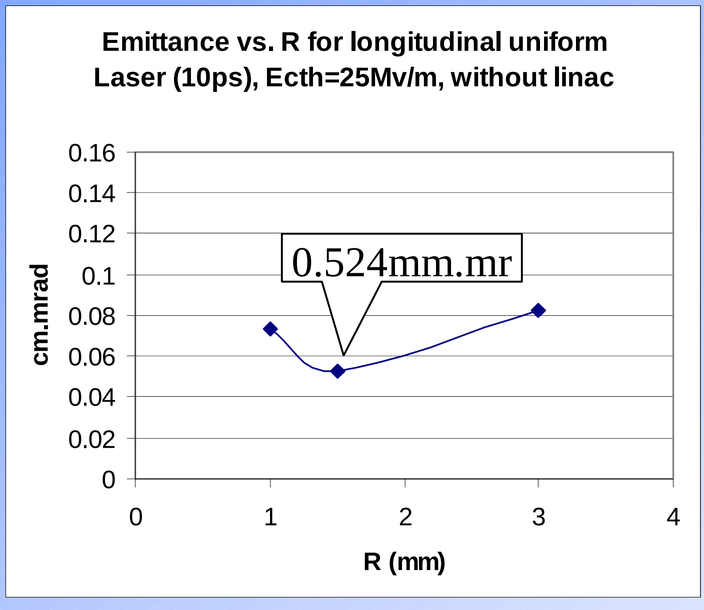
- Layout of L-band RF gun injector for PERL

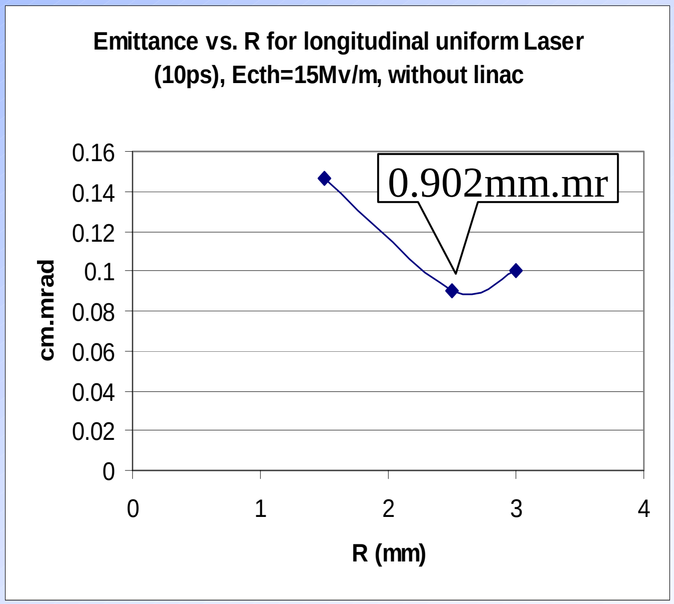


Layout of L-band RF gun injector for PERL

■ Comparison of 25Mv/m and 15Mv/m fields on cathode.

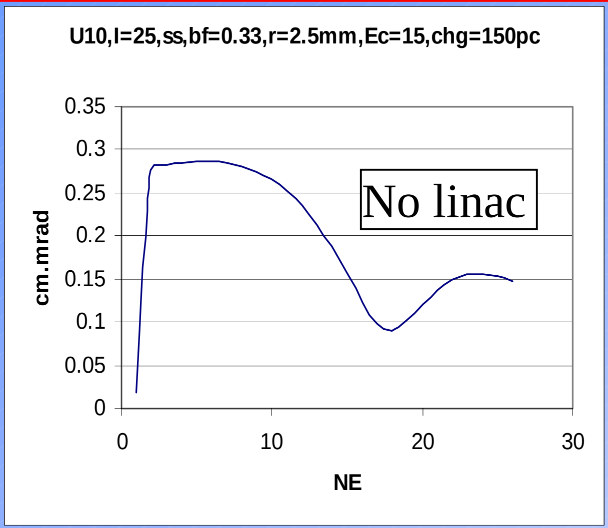
To minimize the heat problem, we decided to concentrate on 15 MV/m case.

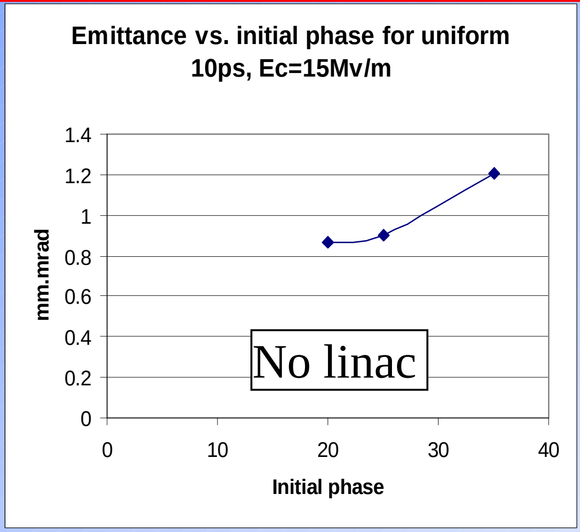


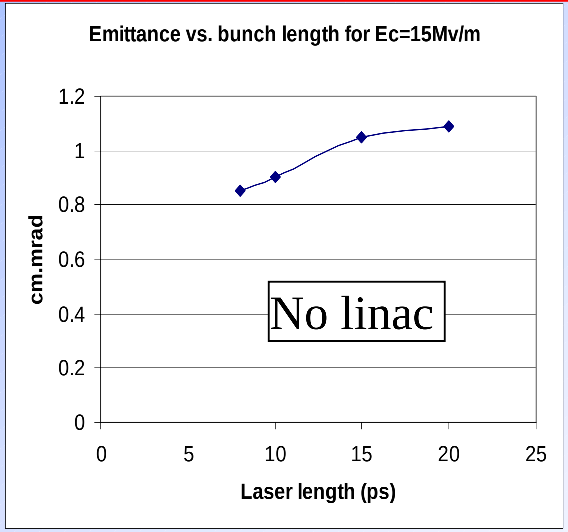


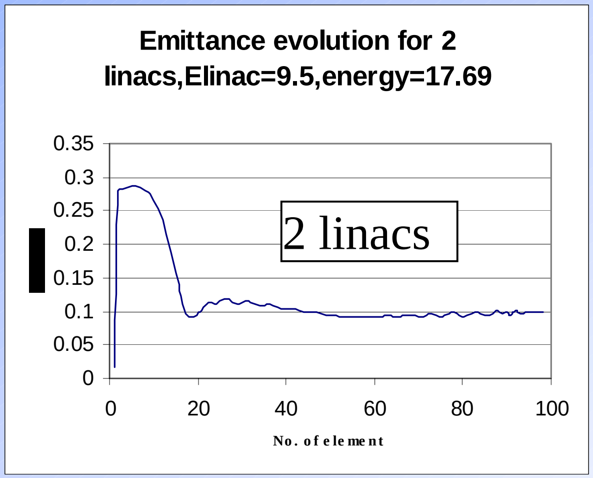
Comparison of 25Mv/m and 15Mv/m fields on cathode

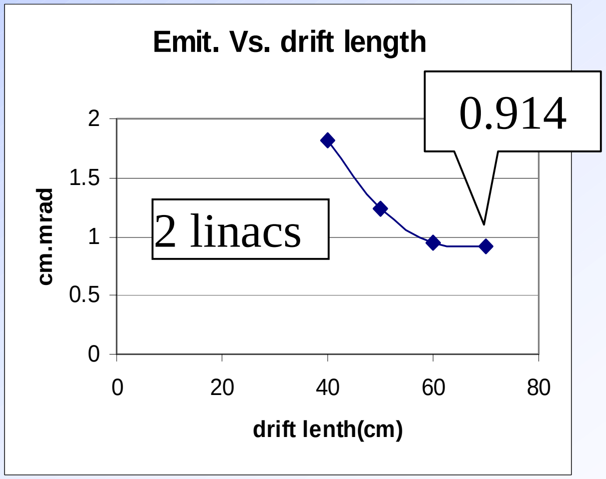
Performance of 15Mv/m field on cathode, no linac. 1.5 gun







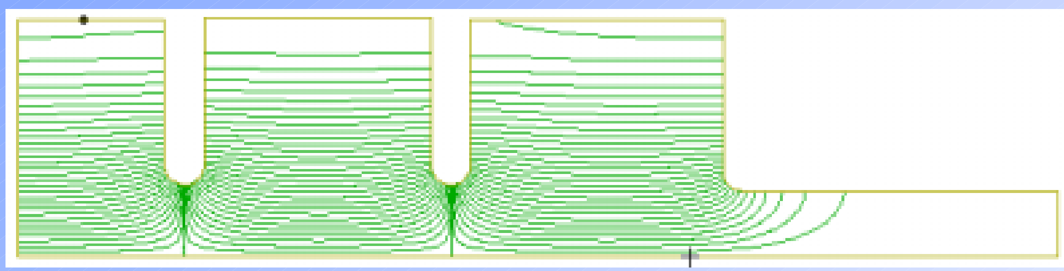




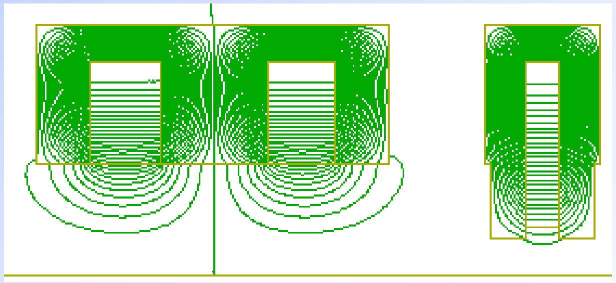
■ 2.5 cell gun.

A. Why use 2.5 cell gun ?

For 30 % increase power, to achieve higher energy at gun exit (1.4---2.35 MeV), which leads to significant reduce in space charge effect.

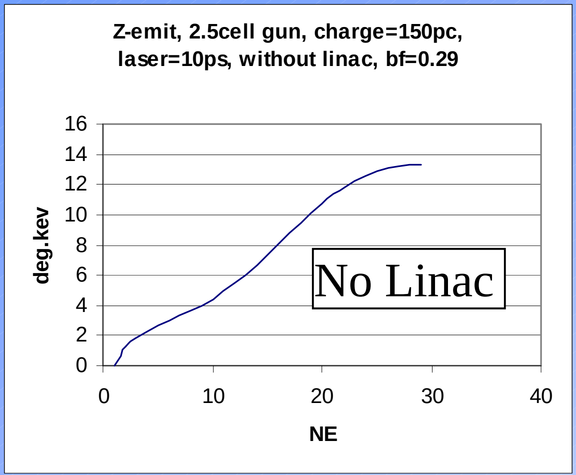


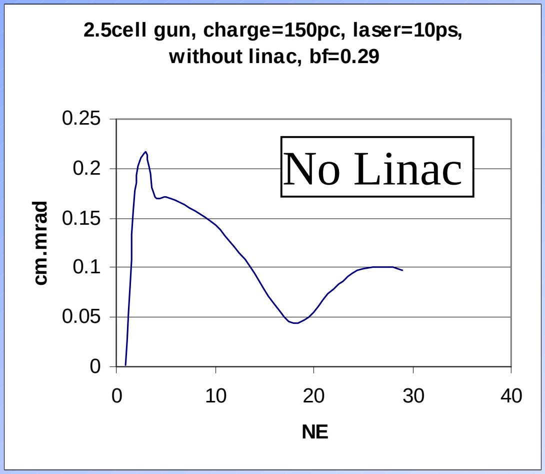
Field distribution for 2.5 cell gun

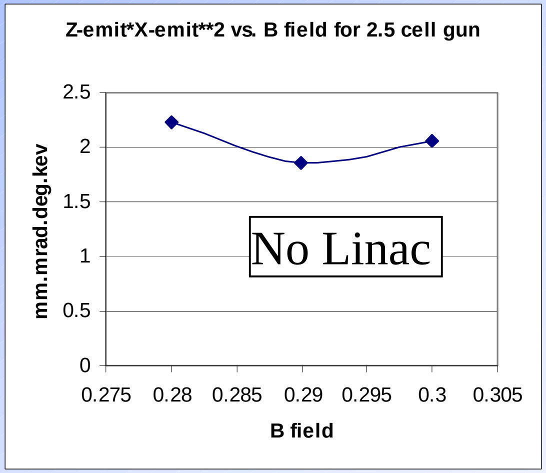


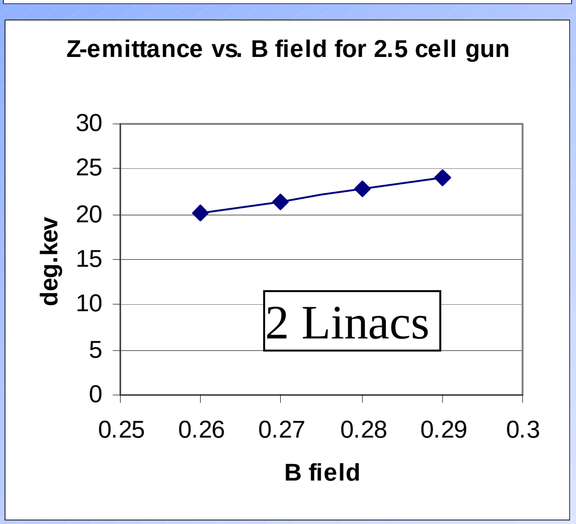
Solenoid for 2.5 gun

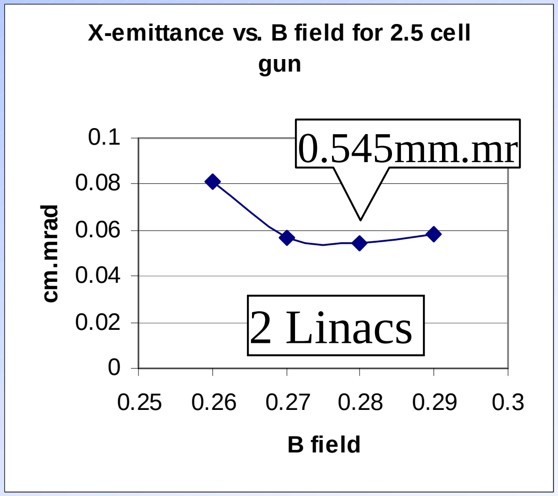
■ Performance of a 2.5 cell gun, no bunching cavity

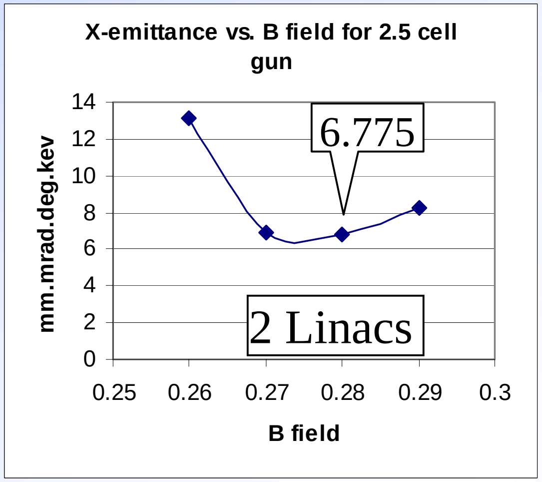


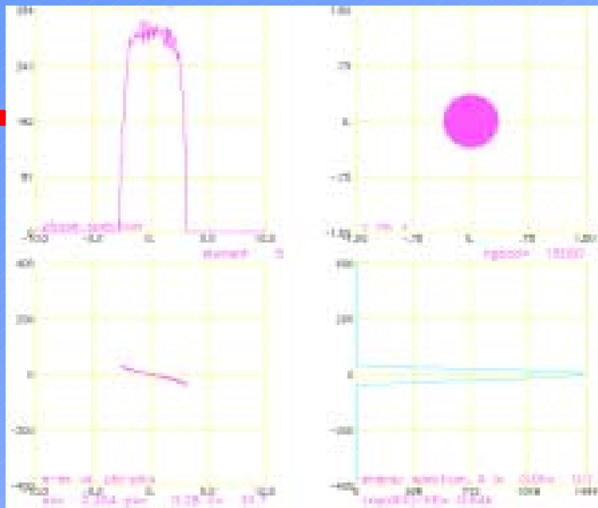
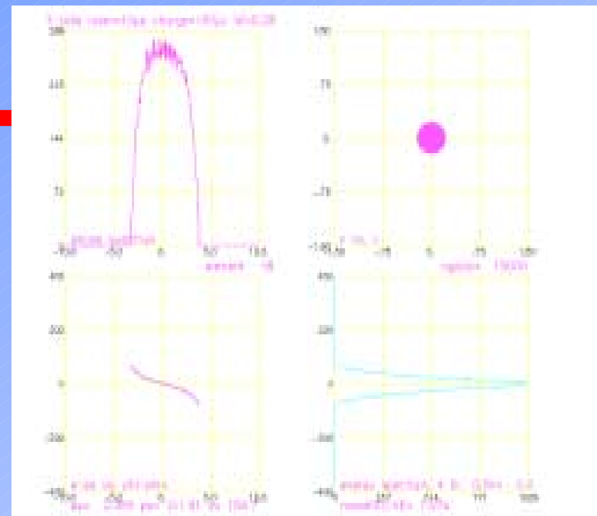
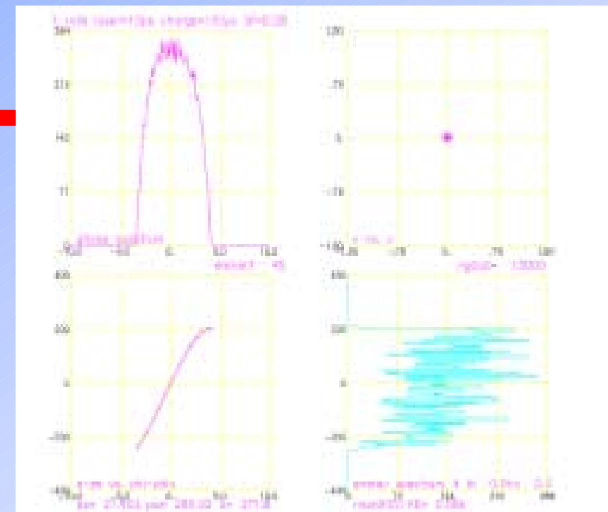


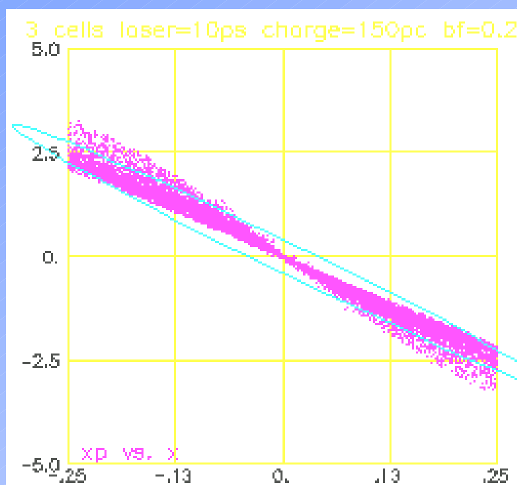




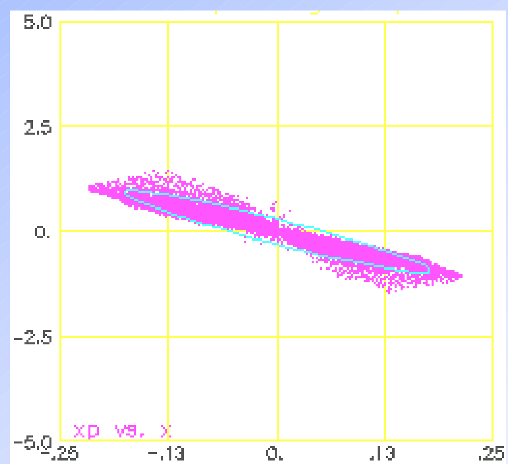






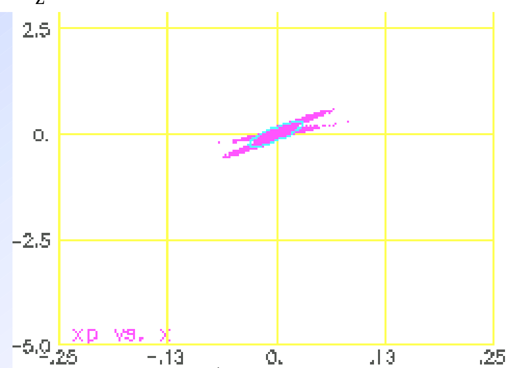
Gun exit



Linac entrance

Energy=21.9, RMS(dkE)/kE=0.58%

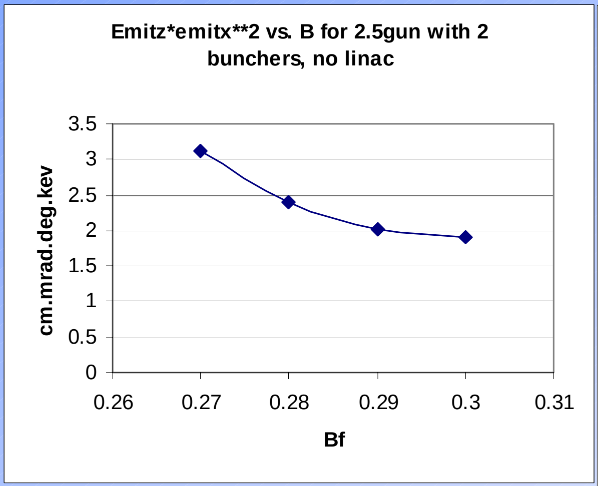
σ_z = 1.24mm



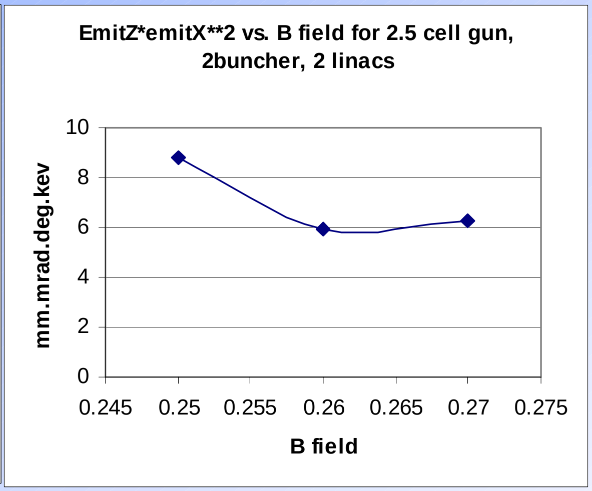
Linac exit

2.5 cell with bunching cavities.

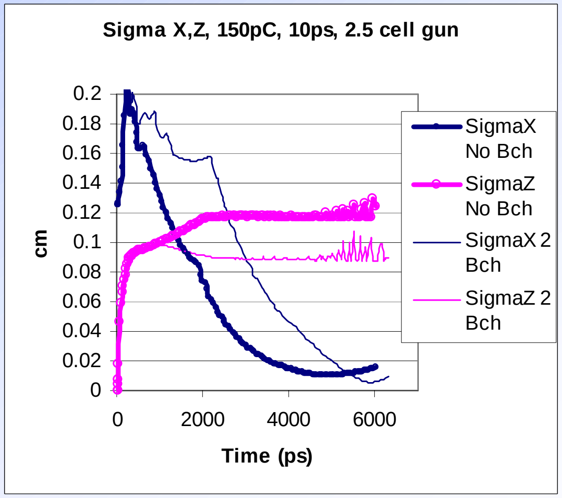
The bunching cavity is used for the purpose of bunching beam before entering linac. But by using 2.5 cell gun, beam energy is a little bit too high for bunching. In case E=2.35Mev, it needs 3% energy spread and 1m drift space to compress 1mm. So, this way may not be efficient. But it does work.



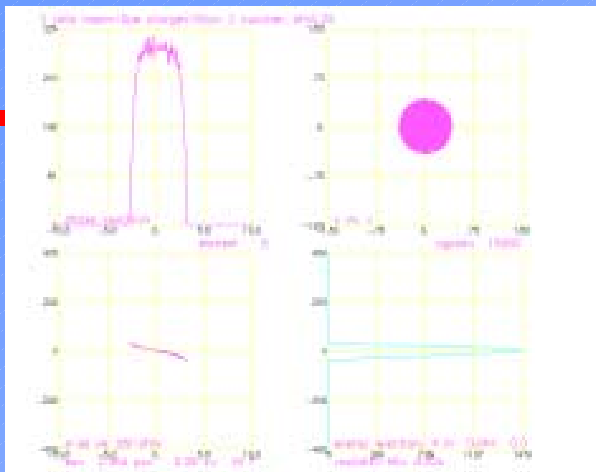
No linac

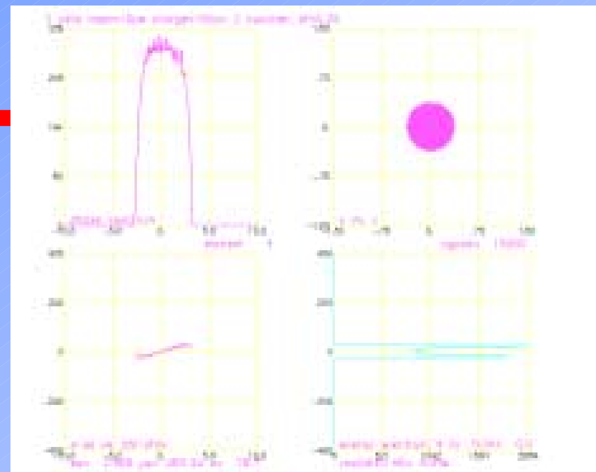


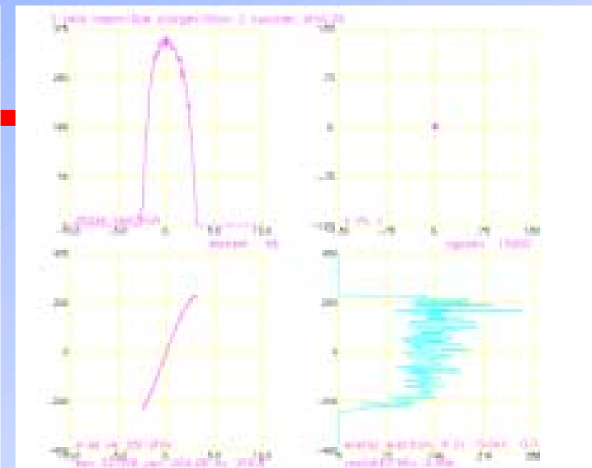
2 linacs



σ_z and σ_x



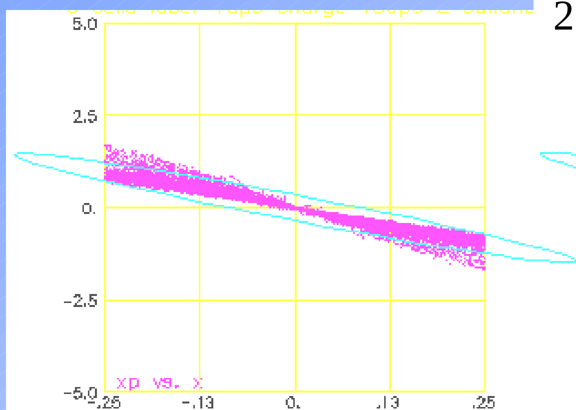


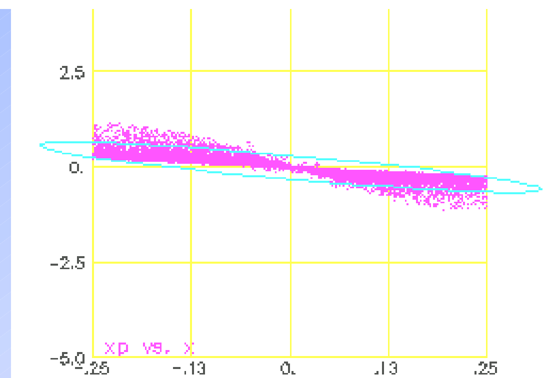


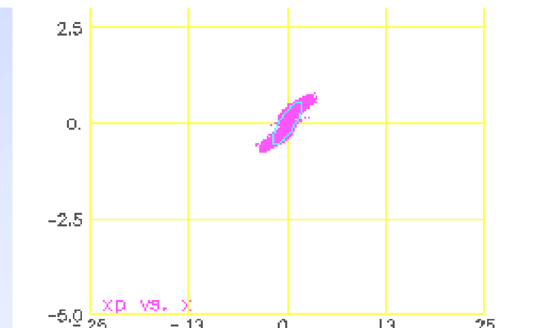
2.5 cell gun, 2 bunchers, 2 linacs

Energy=22.1, RMS(dkE)/kE=0.58%

σ_z = 0.891 mm







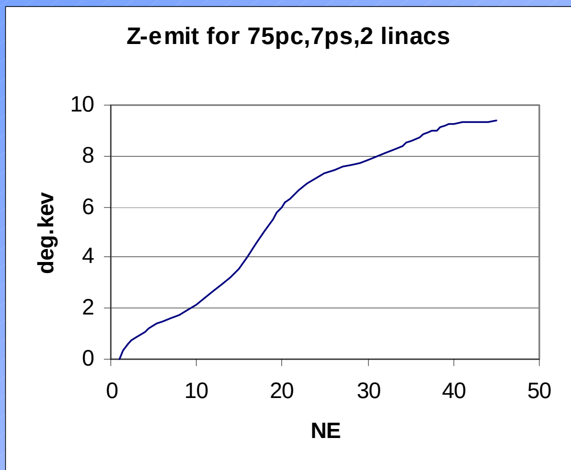
Gun exit

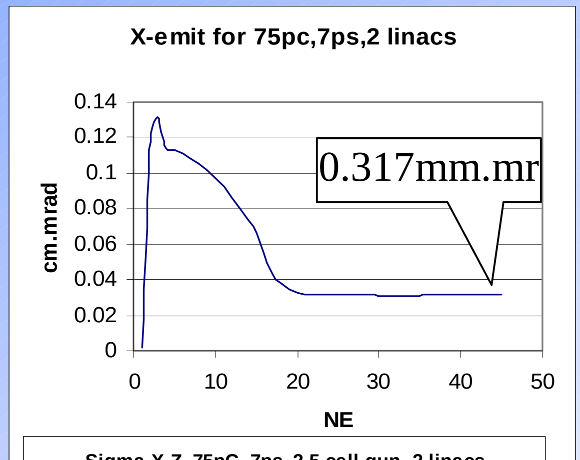
Buncher exit

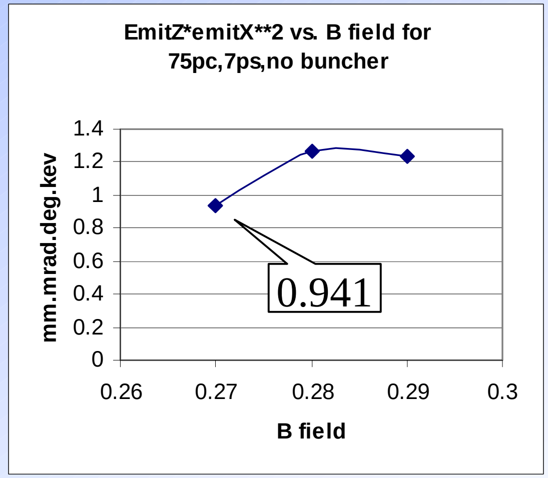
Linac Exit

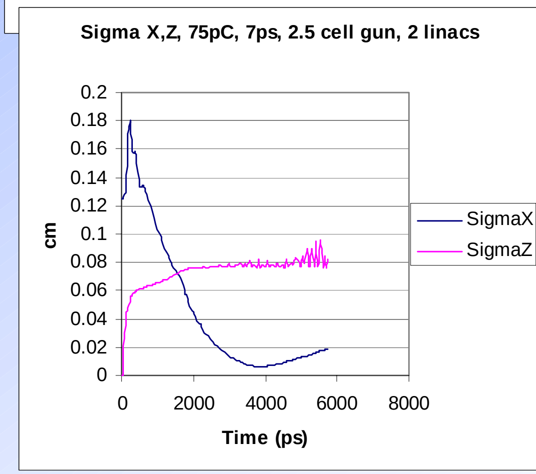
■ 75 pC, 7ps, 2.5 cell gun, no bunching cavity

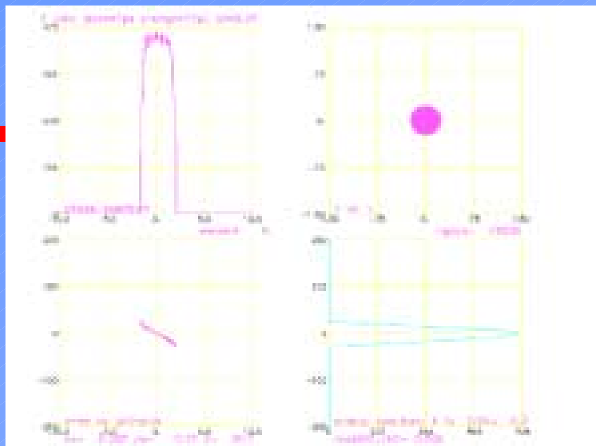
As space charge becomes lower, performance is much better, $\varepsilon_z \times \varepsilon_x^2$ is 1/7 that of 150pc. σ_z = 0.828mm,

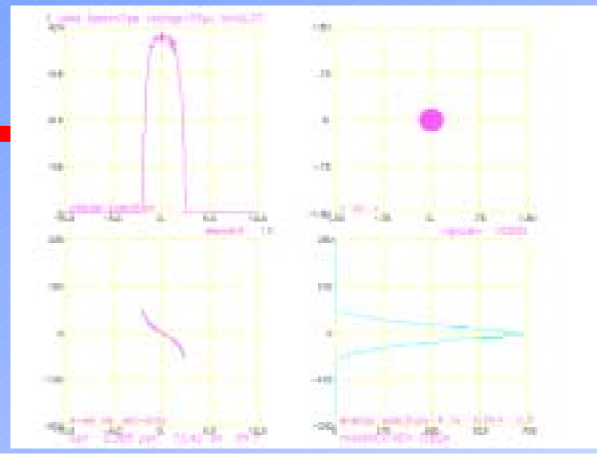


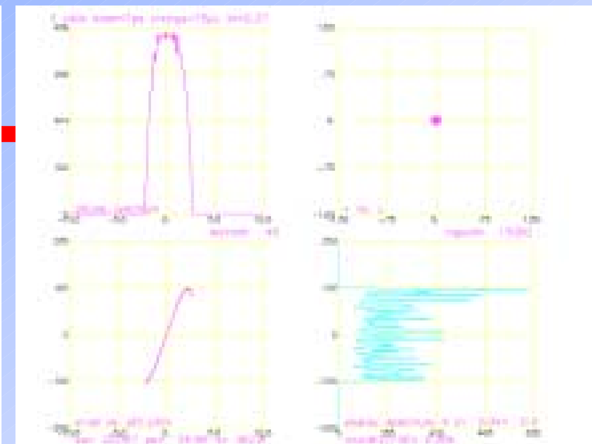








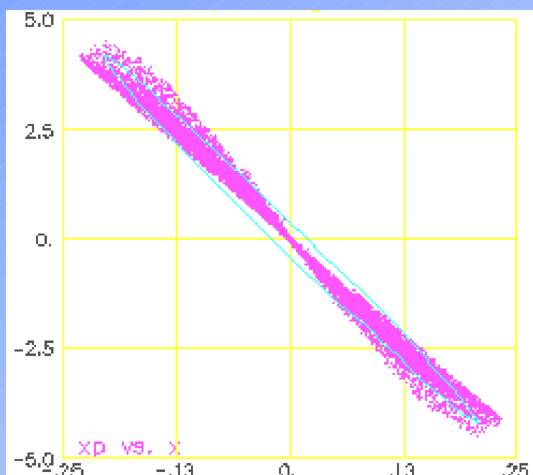




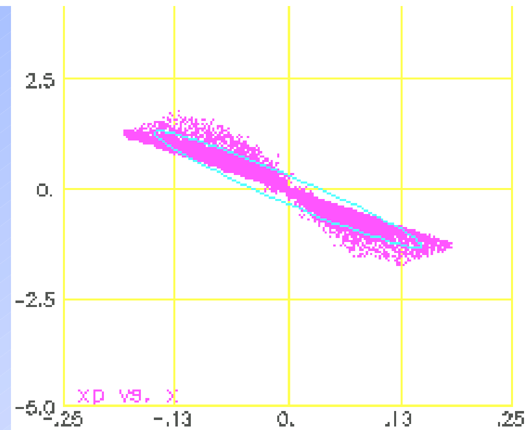
75pc,7ps,2.5 cell gun, 2 linacs

Energy=22.1, RMS(dKE)/kE=0.28%

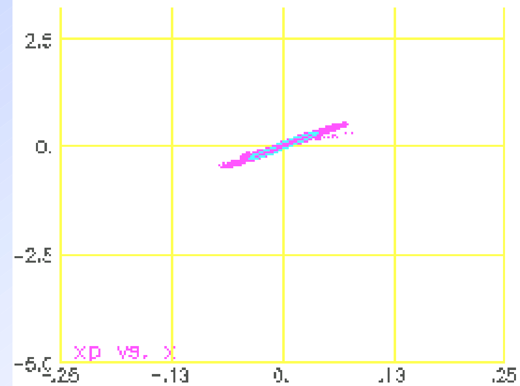
σ_z = 0.828mm



Gun exit

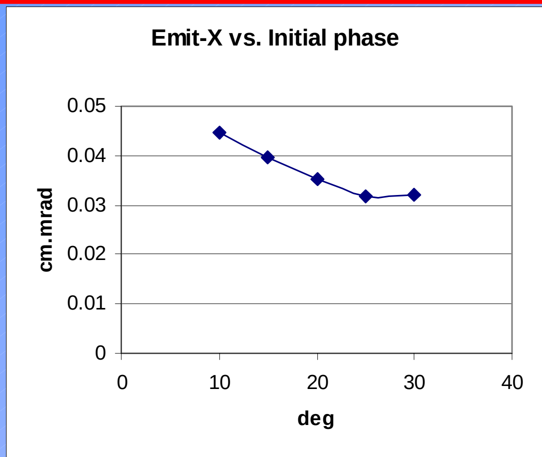


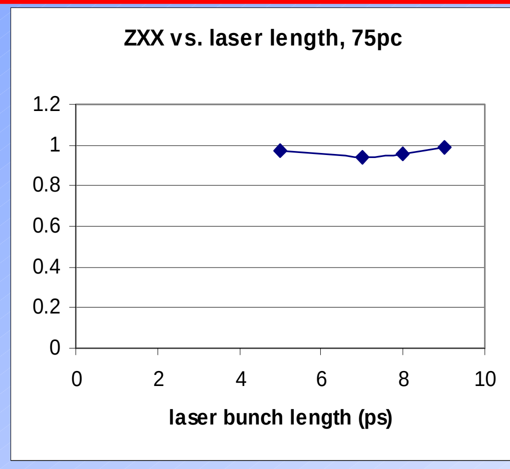
Linac entrance

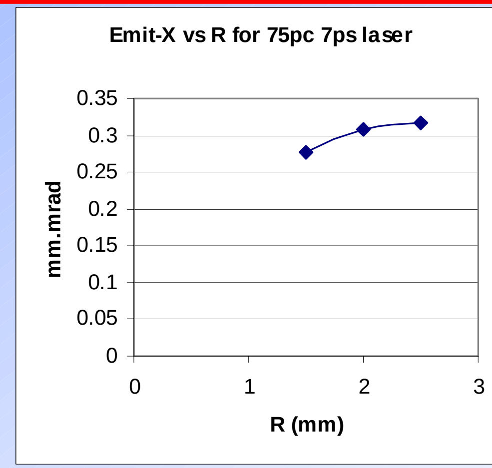


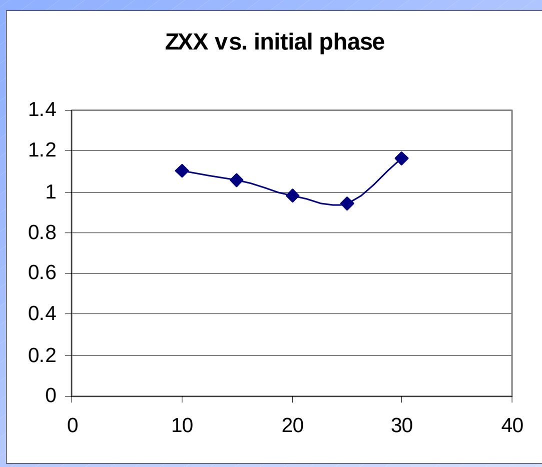
Linac exit

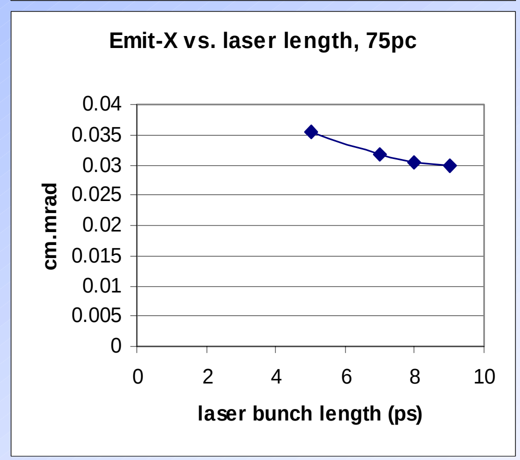
■ 75 pC, 7ps, 2.5 cell gun, no bunching cavity, optimization

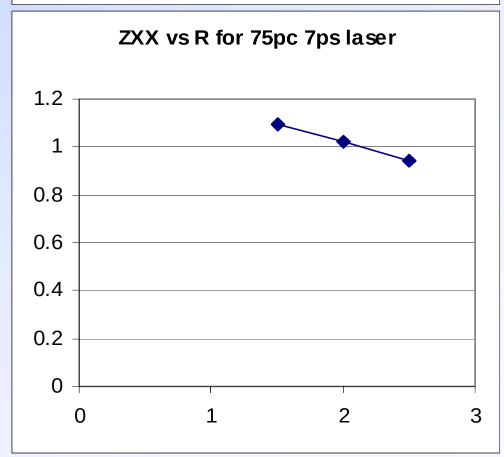








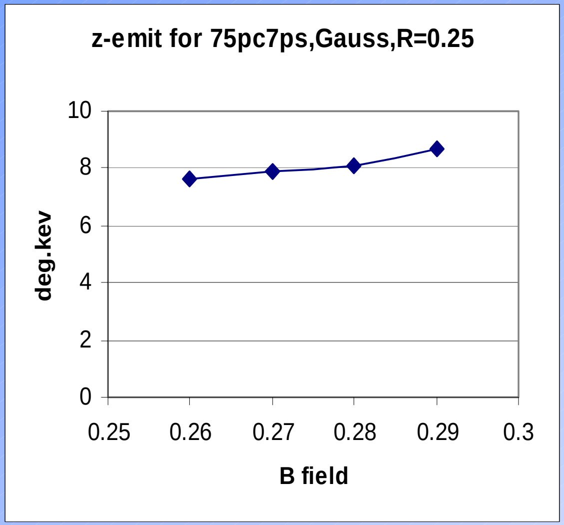


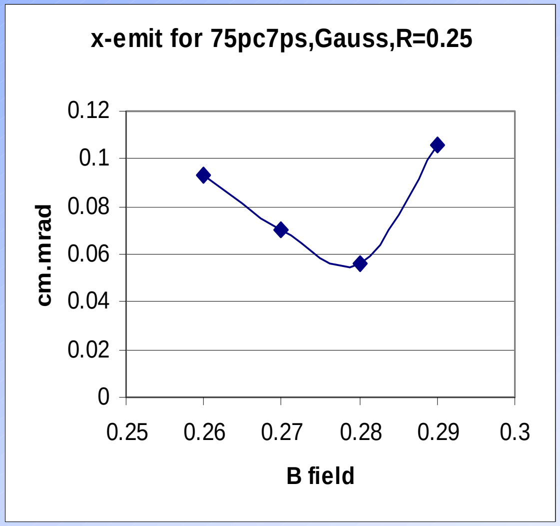


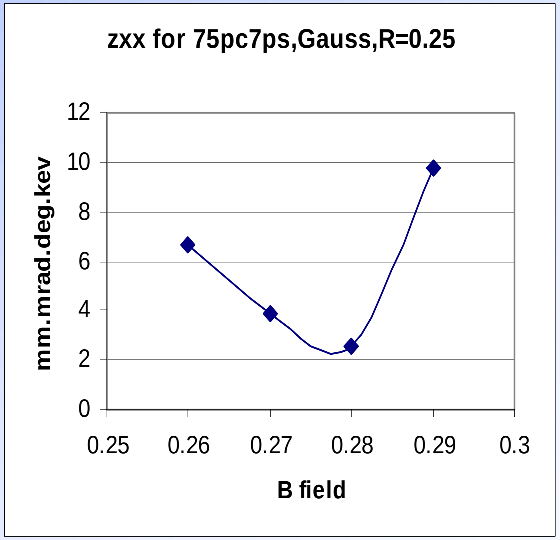
Initial Phase　　Bunch Phase　　R

■ 75pc, Gaussian, FWHM 7ps, 2.5 cell gun

As the technique of shaping longitudinal laser distribution is difficult, using longitudinal Gaussian distribution can simplify the system and then improve system stability.

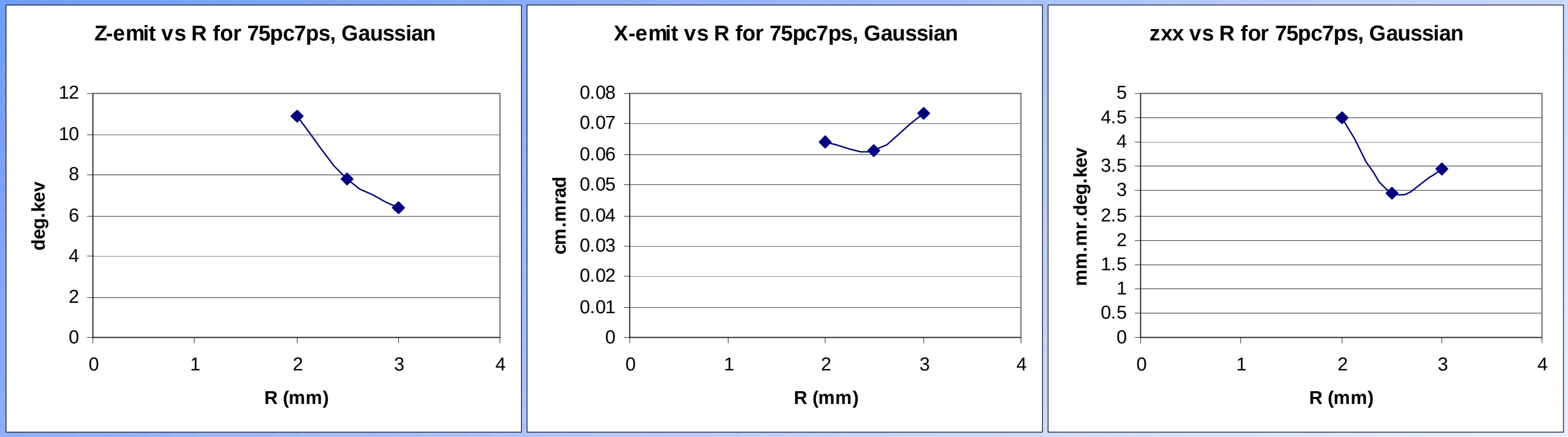




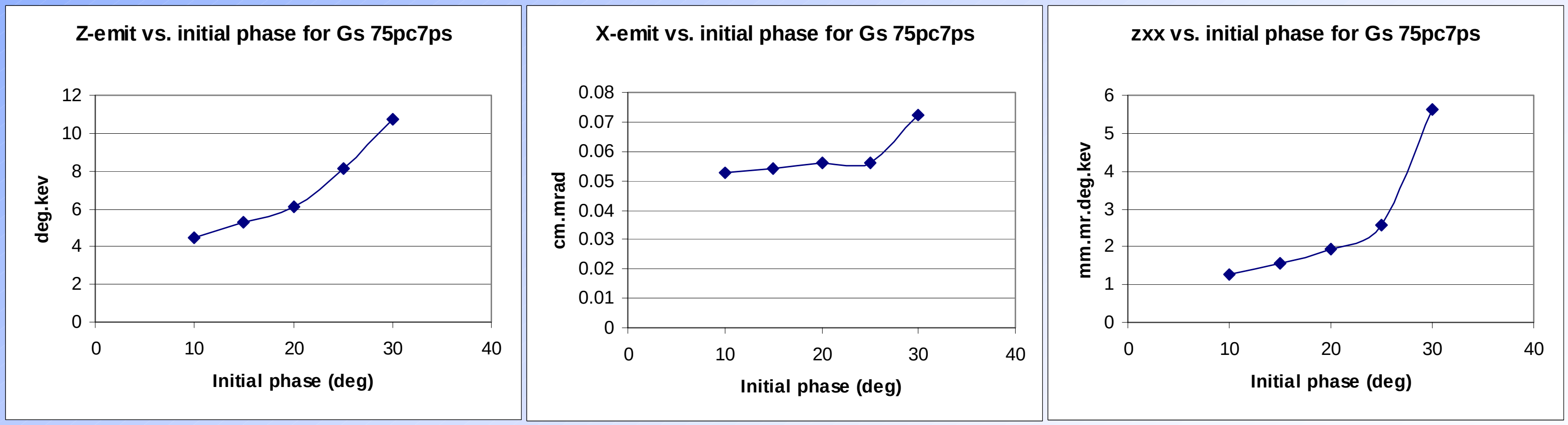


A typical case for 75pc Gaussian distribution

■ Optimization for 75pc, 7ps, Gaussian.



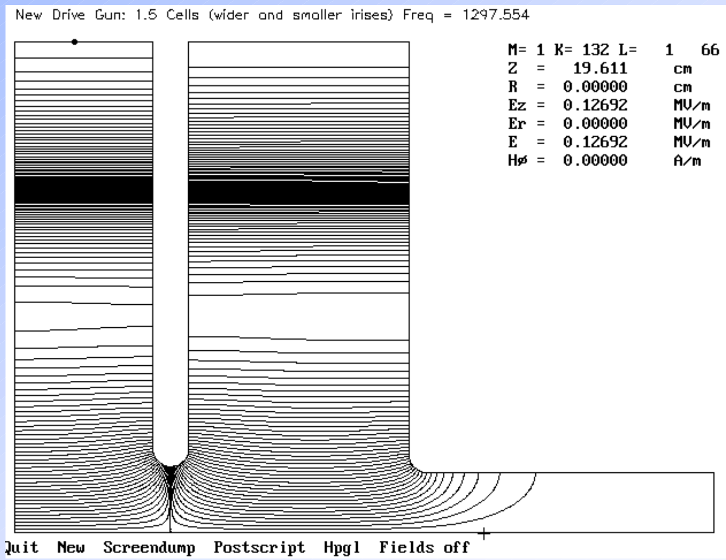
Z-emit,X-emit and ZXX vs. R



Z-emit,X-emit and ZXX vs. initial phase

■ Higher order mode cavity.

By using a gun working at high mode can increase its size. The total power loss on wall increases 60%, but the power dissipation density on wall decreases 60%, which can relieve the heat handling problem. As the field distribution is almost the same as original gun, beam dynamics do not change much. The problem is it will be difficult to apply enough solenoid field in gun because the diameter becomes larger.



Conclusion and Summary

- **L-band photocathode RF gun is capable of producing PERL quality beam.**
- A 1.5 cell L-band with 25Mv/m can produce beam required by PERL.
- 2.5 cell gun is better than 1.5 cell gun. Assume the electric field on cathode we can achieved is 15Mv/m, by using the 2.5 cell gun, for charge =150pC, we can reach at least the following beam performance at linac exit:

  Energy=21.9Mev, RMS(dkE)/kE=0.58%, $\sigma_z=1.24mm$,
  $\varepsilon_z=22.8deg.kev$, $\varepsilon_x=0.545mm.mrad$,
  $\varepsilon_z \times \varepsilon_x^2=6.775mm^2.mrad^2.deg.kev$.
- *For a 75pC charge, the performance is improved greatly.*
  Energy=22.1Mev, RMS(dkE)/kE=0.28%, $\sigma_z=0.828mm$,
  $\varepsilon_z=9.364deg.kev$, $\varepsilon_x=0.317mm.mrad$,
  $\varepsilon_z \times \varepsilon_x^2=0.941mm^2.mrad^2.deg.kev$.
- To simplify the system and improve its stability performance, longitudinal Gaussian distribution laser is considered. We found that the lower the initial phase, the better the performance. When ϕ_I=10deg, $\sigma_z=0.673mm$
  $\varepsilon_z=4.464deg.kev$, $\varepsilon_x=0.529mm.mrad$,
  $\varepsilon_z \times \varepsilon_x^2=1.249mm^2.mrad^2.deg.kev$.

Conclusion and Summary

- Using higher mode cavity RF gun can reduce the power density on the gun cavity wall. More geometric optimization could lead to power reduction 10%.
- More studies need to be done, such as:

A. Performance of higher order mode gun.

B. Study the possibility of shaping the cathode to increase RF focusing near cathode.

C. Parameter optimization.

D. Thermal stress and heat flow calculation are needed

We would like to express our gratitude to Dr W. Gai and M. Conde for providing their gun input files.